3. FEEDSTOCK SUPPLY

This section summarizes biomass feedstock resources, characteristics and availability, delivered prices and requirements for processing, and the impediments and barriers to procurement.

Biomass resources – characteristics and availability

Biomass resources are generally classified into five major categories – urban wood wastes, mill residues, forest residues, agricultural residues, and dedicated energy crops. The availability, characteristics, and costs of acquisition of each of these resources are very different. Availability and price estimates for urban wood wastes and forest residues are highly uncertain and depend on local conditions. Availability of mill residues and agricultural residues can be estimated more precisely; however, prices depend on local market conditions and, in the case of agricultural residues, cropping patterns and environmental restrictions. Energy crops are not currently grown as a fuel feedstock. Availability and price is therefore more speculative. More detailed discussion on each of these feedstocks is summarized below. Discussion of the specific resource methodologies and data sources can be found in Walsh et al., 2000.[1] In addition, there are numerous other useful studies that have estimated biomass feedstock availability, including Wiltsee (1998), Rooney (1998), Fehrs (1999), Antares (1999), and Goldstein (2000).

Urban wastes.

Urban waste is a generic category that encompasses a variety of woody materials, such as yard and tree trimmings, site clearing wastes, pallets, and packaging materials, that can be diverted from municipal solid waste (MSW) landfills and possibly composting facilities. Urban wood wastes also include construction and demolition debris that is typically disposed of in construction and demolition (C/D) landfills. The physical characteristics of these materials varies widely. Yard and tree trimmings are a relatively clean woody fuel that have a moisture content of 35%-60% depending on the vegetation type and season (Badger, 2002). Site clearing wastes are similar to tree trimmings except they may contain rocks and dirt, if stumps are not separated. Yard trimmings and site clearing wastes are often processed with drum chippers that can blow the chips directly into a chip van for transport. Processing requirements are therefore minimal once the material has been separated from the MSW stream. Pallets and packaging materials are also relatively high quality resources with moisture content tending to be rather low (<15%). C/D debris contains many different wastes including chemically treated wood and non-woody materials, such as metal, concrete, wallboard, and shingles. These non-woody materials must be source separated or taken to a recycling center for separation and recovery. Pallets and C/D debris are usually processed with hammermills to break apart. Magnets and non-ferrous metal detectors, screens, and hogs may also be required for processing.

Estimating quantities and delivered prices of urban wood wastes is confounded by a general lack of data. For the most part, regional and state-level surveys, per capita waste generation coefficients, and compositional analysis data are used to estimate availability. Walsh et al. (2000) estimated total annual urban wood wastes at about 36 million dry tons. This estimate is based on surveys of the wood waste deposited in MSW landfills, C/D landfills, and compost facilities. These data indicate that 6%-8% of material taken to MSW landfills is wood, 20-50% deposited at C/D landfills is wood, and 80%-90% taken to compost facilities is wood. The product of these composition fractions and total waste deposited, corrected for moisture content, provides an estimate of total availability.

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[1] Walsh et al. (2000) is currently being updated. The updated report will include the state-level biomass resource database and a selected county-level database.

The delivered prices at which urban wood waste is available are highly location specific. Delivered prices can be estimated as a function of an average processing cost (e.g., hammermills and separation), an average transport cost including loading and unloading, less some fraction of the landfill disposal or tipping fee. Local and state regulatory policies (e.g., recycling requirements and certification), the extent of competing uses, such as mulch and compost, as well as other factors can affect costs. Given the uncertainties about availability, location-specific factors affecting delivered prices, and anecdotal evidence, Walsh et al. assume that 60% of the resource could be available at delivered prices of $25/dry ton or less and the remainder at delivered prices of less than $35/dry ton. In some cases, delivered prices could be negative due to the presence of high offsetting tipping fees. For example, Goldstein (2000) reports state landfill tip fees ranging from $13 to $70/ton and Wiltsee (1998) shows supply curves for urban wastes ranging from a low of -$80/ton to over $20/ton. The approximate breakdown of the delivered prices for urban wood wastes is summarized below.

	Avoided landfill tipping fee	Collection & processing	Transport	Total
Urban wood wastes	($0-$100)	~$20-$25	$5-$10	<$25-$35

Mill residues.

Primary mill residues are classified into three types–bark stripped from logs, coarse residues (chunks and slabs), and fine residues (shavings and sawdust). These residues are generated in the processing of lumber, pulp, veneers, and composite wood fiber materials. Moisture content of this material is about 20%. These residues are advantageous because they tend to be clean, uniform, and concentrated at a single source. However, nearly all of these residues are currently used as fuel or as inputs in the manufacture of products. Very little of this resource is currently unused. For bark, about 80% is used for fuel with 18% used in low-value products (e.g., mulch). For coarse residues, about 85% is used in the manufacture of fiber products with about 13% used for fuel. About 55% of the fine residues are used as fuel with 42% used in products.

Although most mill residues are used, payments to mill operators greater than the residue's value in their current use could make them available as a fuel feedstock. This is especially true of the mill residues used on-site in relatively low efficiency boiler systems to produce heat and steam (Walsh et al., 2000). Walsh et al. (2000) report anecdotal evidence suggesting that residues used on-site for low-value energy purposes could be purchased for $15-25/dry ton and residues used to produce higher-valued wood fiber products could be purchased for about $30-40/dry ton. Payments to mill operators to make these residues available could thus range from $0 to $40/dry ton. Some minimal processing of the residues could also be required. In total, most of the unused residues could be obtained at prices below $25/dry ton and residues in current use could be had for $15-$40/dry ton.

	Mill payments	Collection & processing	Transport	Total
Mill residues	$0-$40	$0-$5	$5-$10	<$25-$55

Forest residues.

Forest wood residues include two sources–logging residues and the rough, rotten, and salvable dead wood (RRSD). Logging residues are the unused portion of the growing stock that are cut or killed by harvest operations and left behind. These materials include small branches, limbs, tops, and leaves. According to Smith and Sheffield (2000), logging residues account for about 6% of softwood growing stock removals and about 11% of hardwood removals. The total amount of logging residue produced annually is about 11 million dry tons. The RRSD resource is considerably larger than the logging residues resource. Rough trees are those that do not contain a sawlog (i.e., 50 percent or more of live cull volume) or are a non-merchantable species. Rotten trees are trees that do not contain a sawlog because of rot (i.e., 50 percent or more of the live cull volume). Salvable dead wood includes downed or standing trees that are not considered merchantable. The size of this resource is vast and easily exceeds 1 billion dry tons. However, most of this RRSD material is inaccessible due to the absence of roads or access, is not economically retrievable with current technology, or is located in environmentally sensitive areas. About 10% of the RRSD resource might be considered available after accounting for access, material retrieval efficiency, and environmental restrictions (Walsh et al., 2000).

Recovery of the RRSD material (i.e., whole-trees) is done most cost-effectively with conventional feller-bunchers, skidders, and whole-tree chippers. Recovery of logging residues from the commercial harvest of timber and fiber operations at landings requires a whole-tree chipper or tub grinder. In both cases, chipping converts low-quality material into easily handled wood chips, which can be blown directly into a tractor trailer and chip van for transport. Quality of the material is generally high since much of the dirt debris is removed by differences in particle density when the chips are blown into the transport trailer (Badger, 2002). Although the chips may be relatively uniform in size they are often mixed with long slivers and splinters from small branches and limbs. For this reason, screening may be required before they are introduced into a wood energy handling system. The moisture content for both sources ranges from about 40-60%.

Delivered prices for forest residues could include a stumpage fee for gaining access to the material, collection costs (felling, skidding, and chipping), and hauling (including loading/unloading). Collection costs will depend on the scale of operation, utilization of the equipment, and the size and density of the available material. Logging residue collection costs also depend on whether the material is collected concurrently with the commercial timber or pulp operation or whether removal is done after the commercial operation. Hauling costs for forest residues are generally higher than the other biomass resources because roads may be unpaved, curvy, and otherwise limit truck size and travel speeds.

	Stumpage	Collection	Transport	Total
Logging residues	<$5	$10-$30	$5-$20	<$25-$55

Agricultural residues.

Corn stover and wheat straw are the two primary sources of agricultural residues. Other grain crops are either limited in acreage or else the amount of residue is small. The quantity of corn stover and wheat straw available depends on grain yield (bu/acre), total grain production or acreage, and the amount of residue that must be left to maintain soil quality (i.e., nutrients and organic matter) and limit erosion. These environmental sustainability restrictions differ by crop and rotation, soil type, field slope, weather conditions, and tillage system. Under average conditions, about 30 to 40 percent of corn stover and wheat straw residues may be removed. Currently, most of these agricultural residues are left on the ground and plowed under. A major limitation of agricultural residues is the limited collection season–usually a couple of months following grain harvest. Year-round utilization of these resources may require storage of up to ten months.

The costs of gathering these materials include mowing, raking, baling, loading and unloading, storage, and hauling. Collection costs using conventional baling equipment range from about $20-$25/dry ton. Uncovered storage of the bales for year-round use adds another $5/dry ton. As reported by Walsh et al. (2000), typical payments to farmers to compensate for lost nutrients and environmental benefits can vary between $10-$15/dry ton. Haul costs depend on distance and numerous logistical factors, such as crop acreage density, proportion of farmers selling residues, etc.

	Collection	Farmer payments	Storage	Transport	Total
Agricultural residues	\$20-\$25	\$10-\$15	\$5	\$5-\$10	<\$35-\$55

Dedicated energy crops.

Dedicated energy crops include short rotation woody crops (SRWC) such as hybrid poplar and hybrid willow, and herbaceous crops such as switchgrass. Management practices for each crop are regionally dependent. For hybrid poplars, trees are planted at a density of about 500-600 trees/acre and are harvested after 6 to10 years of growth depending on the region of country and growth rates. Although these trees will re-sprout, current management guidelines suggest replanting with improved clones following harvest. Hybrid willow is relegated to the northern states. It is planted at much higher densities (about 6200 trees/acre) and harvested after 4 years of growth. Hybrid willow stands are regenerated by coppicing with as many as 7 succeeding coppice stands expected from the initial establishment. Hybrid poplars are harvested with conventional forestry equipment (feller-bunchers, skidders, and whole-tree chippers) and willow with some form of combine machine. Both woody crops are delivered as whole-tree chips. The establishment of switchgrass is similar to that of a conventional hay crop. Once established it can produce for about 10 years before replanting is required. Switchgrass is harvested with conventional baling equipment and is delivered to conversion facilities as large round or rectangular bales. The ability to use existing on-farm equipment is a major advantage of switchgrass over tree crops.

Energy crops are not currently grown as fuel feedstocks, but research indicates that energy crops would be produced provided farmers could earn a risk-adjusted return equal to that from traditional agricultural crops. Walsh et al. (2000) used an agricultural sector model to estimate the quantities of energy crops that would be grown at various energy prices and assuming given agricultural policies, such as Conservation Reserve Program acreage. Analysis results indicate that these crops could be produced at delivered prices starting about \$35/dry ton.

	Production/harvesting	Hauling	Total
Poplars	\$50-\$60	\$5-\$10	<\$55-\$70
Willows	\$60-\$65	"	<\$65-\$75
Switchgrass	\$30-\$45	"	<\$35-\$55

Regional availability

It is estimated that about 24 million dry tons of biomass resources might be available nationally to conversion facilities at delivered prices of about \$25/dry ton or less (\$1.60/MMBtu). The amount of biomass resources available increases more than fourfold at prices under \$35/dry ton (\$2.20/MMBtu). At prices under \$55/dry ton (\$3.40/MMBtu), over 510 million dry tons might be available annually. Figure 3.1 summarizes national biomass feedstock availability at delivered prices ranging from under \$25 to under \$55/dry ton. State-level estimates are provided in Table 3.1. No assumptions about the spatial distribution of resources within a state are made. As such, proposed conversion facilities may not be within an economically feasible transport distance. Feasibility studies of proposed conversion facilities must therefore conduct detailed local analyses to verify feedstock availability, prices, and reliability.

Generally, urban wood wastes are the least expensive followed by mill residues, forest residues, agricultural residues, and energy crops. This ordering reflects more or less the costs of acquisition (offsetting landfill tipping fees) and the significance of collection (or production and harvesting) and processing costs. Urban wood wastes, mill residues, agricultural residues, and forest residues are often available in small and dispersed amounts, creating high transaction costs. Supply reliability and quality requirements may also be difficult to meet consistently. Further, prices do not include any processing of the wastes at the conversion facility. For example, bales would need to be broken and ground, whole-tree chips may need to be screened, and urban wastes may require more specialized processing to remove non-combustible materials. Finally, it should be reiterated that the uncertainty surrounding these estimates is high. Site-specific analyses are required to determine specific estimates of available quantities at given delivered feedstock prices. Bio-resource procurement is complex, costly, and a significant barrier to potential use.

Fig. 3.1. Total U.S. Biomass Resources at Selected Prices

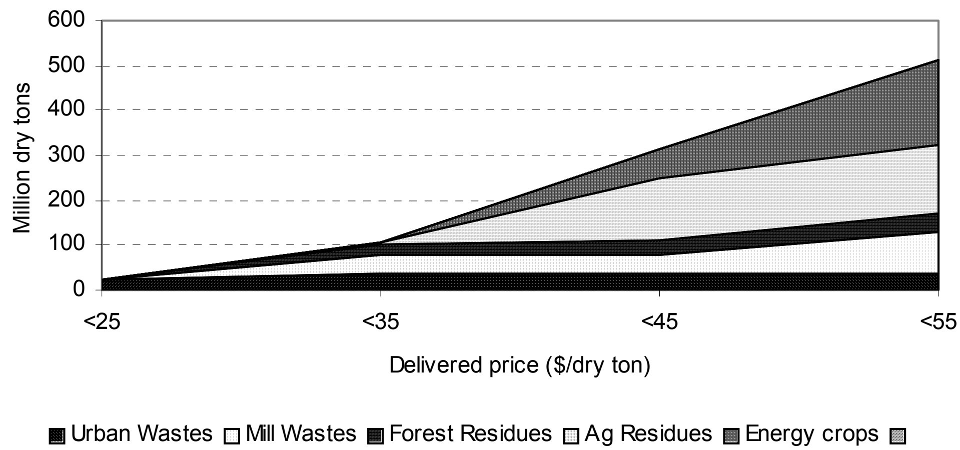

Table 3.1: Estimated Biomass Resources Available by State and Price

State	Delivered price ($/dry ton)			
	<25	<35	<45	<55
	thousand dry tons			
Alabama	841	6,963	10,712	17,682
Arizona	220	575	863	1,100
Arkansas	402	4,092	7,086	13,604
California	1,588	6,158	8,224	11,299
Colorado	181	652	3,357	3,582
Connecticut	247	561	611	906
Delaware	39	95	194	462
Florida	2,762	6,524	6,778	9,533
Georgia	934	6,391	8,541	16,112
Idaho	204	2,572	4,117	7,166
Illinois	435	1,038	26,839	33,359
Indiana	348	994	13,410	18,607
Iowa	174	404	24,583	32,786
Kansas	737	1,283	12,733	21,344
Kentucky	455	1,472	5,758	10,809
Louisiana	516	3,569	7,977	11,834
Maine	151	1,196	1,572	2,214
Maryland	205	543	900	1,959
Massachusetts	419	939	1,027	1,436
Michigan	506	2,468	4,627	12,163
Minnesota	991	2,917	15,494	21,247
Mississippi	599	4,909	10,673	17,931
Missouri	478	1,346	8,030	19,523
Montana	69	1,422	2,159	6,761
Nebraska	114	210	18,467	21,773
Nevada	184	315	333	337
New Hampshire	134	922	1,061	2,016
New Jersey	389	726	791	976
New Mexico	168	424	961	1,082
New York	1,168	3,328	3,885	8,438
North Carolina	669	4,188	5,790	10,856
North Dakota	327	558	2,507	21,043
Ohio	745	1,473	13,018	18,963
Oklahoma	111	3,874	7,816	12,700
Oregon	193	3,341	4,126	9,810
Pennsylvania	572	2,206	2,832	7,427
Rhode Island	30	81	88	116
South Carolina	1,294	4,469	6,332	9,368
South Dakota	132	286	9,602	16,005
Tennessee	878	3,382	10,720	15,233
Texas	1,227	4,222	13,526	20,747
Utah	159	388	648	723
Vermont	41	392	513	1,023
Virginia	599	3,059	5,055	8,715
Washington	297	3,979	5,939	9,920
West Virginia	241	1,361	1,972	3,736
Wisconsin	425	2,450	11,502	14,963
Wyoming	224	552	787	1,466
Total	23,820	105,267	314,535	510,855

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